Space Technology Research Grants

3D Constitutive Relations for An Aligned Carbon Nanotube Polymer Nanocomposite as a Function of Morphology

Completed Technology Project (2011 - 2015)

Project Introduction

Nanostructured polymeric materials are of significant interest for advanced aerospace structures due to their novel mechanical and transport (electrical, thermal, ionic, etc.) properties. The system we intend to study comprises an aligned carbon nanotube (A-CNT) forest embedded in an aerospace-grade unmodified thermoset epoxy resin, forming an aligned-fiber polymer nanocomposite, an A-CNT PNC. As previously demonstrated in our group, by controlling the composite's morphology its properties can be tailored to exhibit significant differences along different material axes (e.g., thermal and electrical transport along conductive CNT axes vs. transverse to them). The A-CNT polymer nanocomposite is of interest in order to develop nano-engineered hierarchical materials comprised of aligned-CNTs in polymer matrices acting in concert with micron-dia. advanced fibers (such as carbon fibers, in a "nanostitch" architecture). Mastery of the use of such material will allow for the engineering of highly specialized aerospace structures with precisely specified properties and desirable properties (e.g. strength-to-weight ratio) far in advance of those presently available for use in aerospace systems. The ability to produce structures with anisotropic material characteristics will also lead to significant weight savings for use in load-bearing components, which are of course vital in any aerospace applications. A novel mechanical densification process developed by our group allows volume fraction to be varied between 1 and 20+%. The work we propose will provide measurements of the linear elasticity tensor for this class of materials, providing a basis for further constitutive model development. The stiffness relation for the A-CNT PNCs as a function of CNT volume fraction will be assessed using standard configurations and optical strain mapping. Significant stiffness biases have previously noted along the different material directions associated with the CNTs, with relative stiffness increases exceeding 100%. Furthermore, strain ranges of linearity are identified and different behaviors are noted in compression vs. tension. Prior work in this epoxy system has shown no discernible effects of the CNTs in the cross-link density or other characteristics (Tg etc.) of the polymer matrix. These findings will allow interpretation of the measured response of the A-CNT PNCs via a number of different avenues, including a computational microstructural investigation of structure-property relations focusing on the morphology of the fiber reinforcements (the CNTs). A finite element model (FEM) will be implemented that captures the effect of CNT 'waviness' (non-collimation) on the resulting homogenized composite properties. Future work to be pursued in the upcoming academic year include expanding this testing technique to explore visco-elasticity effects and large-strain behavior, and modeling work to focus on CNT-CNT interactions. The goal of the research is to use this new data to allow an improved characterization of A-CNT PNCs in order to support their use in actual aerospace applications in the near-term.

Anticipated Benefits

Project Image 3D Constitutive Relations for An Aligned Carbon Nanotube Polymer Nanocomposite as a Function of Morphology

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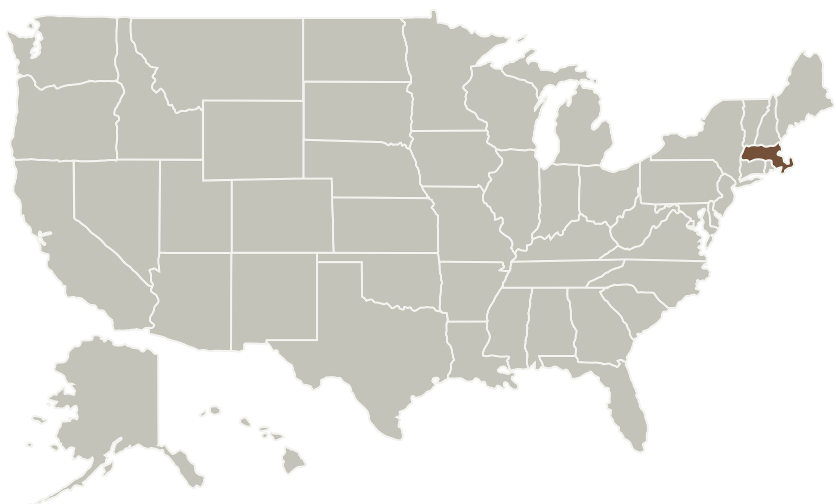
Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Massachusetts

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

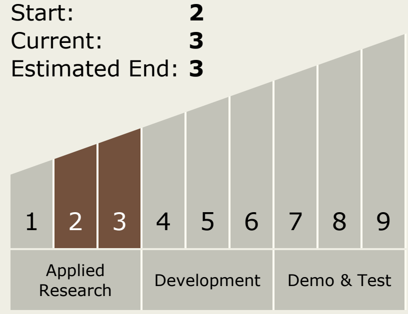
Brian Wardle

Co-Investigator:

Daniel Handlin

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Images

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Project Image 3D Constitutive Relations for An Aligned Carbon Nanotube Polymer Nanocomposite as a Function of Morphology
(https://techport.nasa.gov/image/1709)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.1 Materials
    └ TX12.1.1 Lightweight Structural Materials